U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Role of Renewable Transport Fuels in the United States

ARPA-E Macroalgae Conversion Workshop

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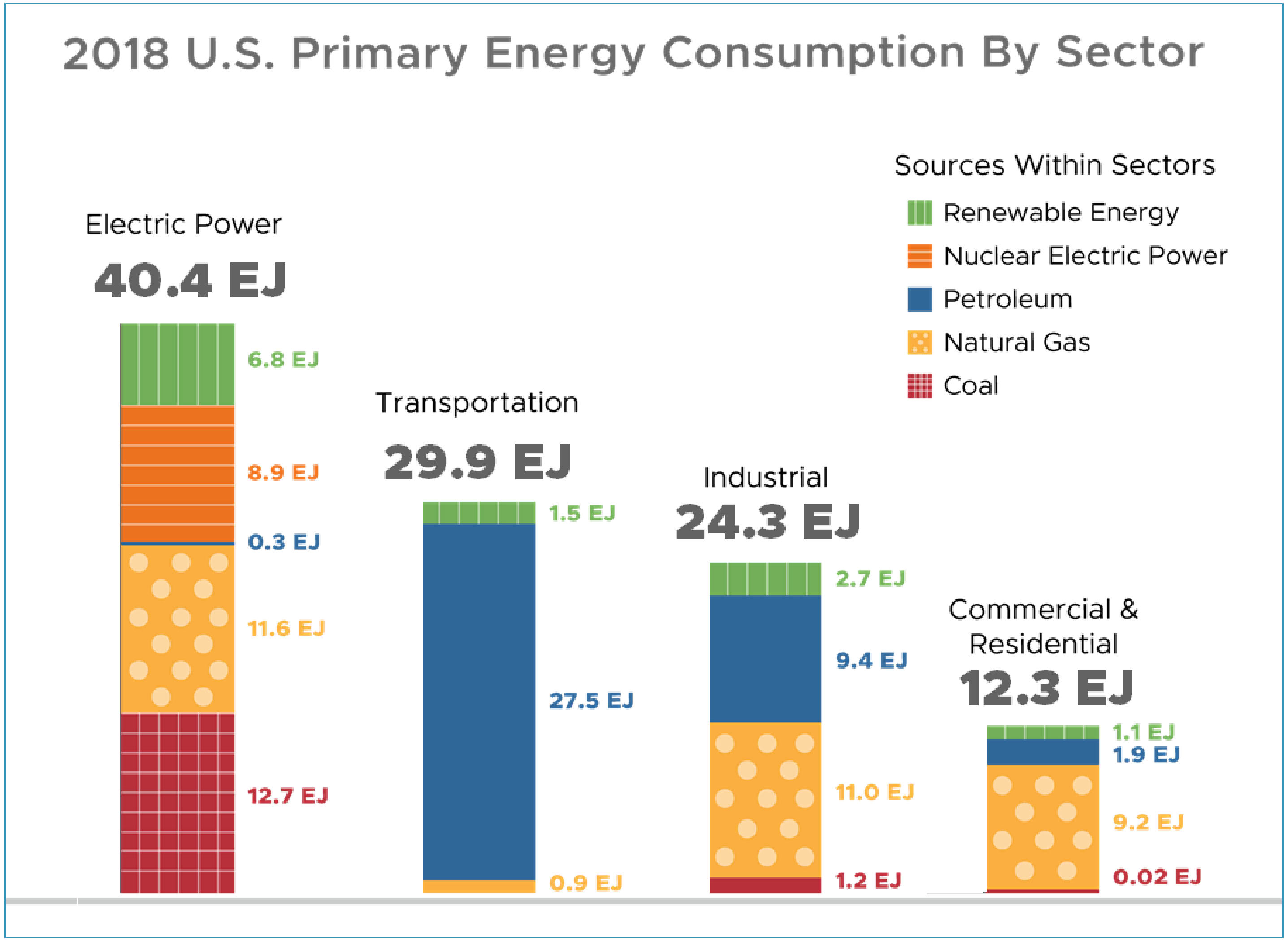
Snapshot of U.S. Energy Use by Sector and Source

The U.S. uses 107 EJ* of primary energy each year

- Coal, 14 EJ
- Natural gas, 33 EJ
- Petroleum, 39 EJ
- Nuclear, 9 EJ
- Renewables, 12 EJ

*1 EJ is equal to 948.45 tBtu



Source: [U.S. Energy Information Administration, Monthly Energy Review, July 2019]

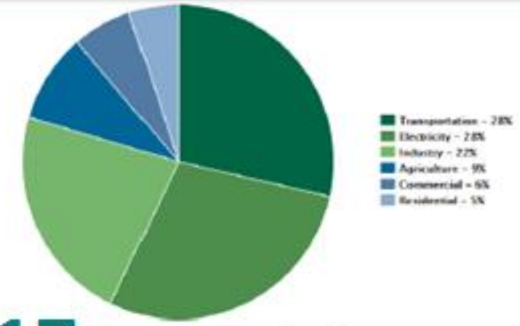
Transportation Uses 28% of Nation's Energy

Every year, we transport 11 billion tons of goods and travel 3 trillion vehicle-miles.

69% of petroleum used for transportation.

86% of it used for on-road vehicles.

Transportation is the 2nd largest expense for U.S. households.

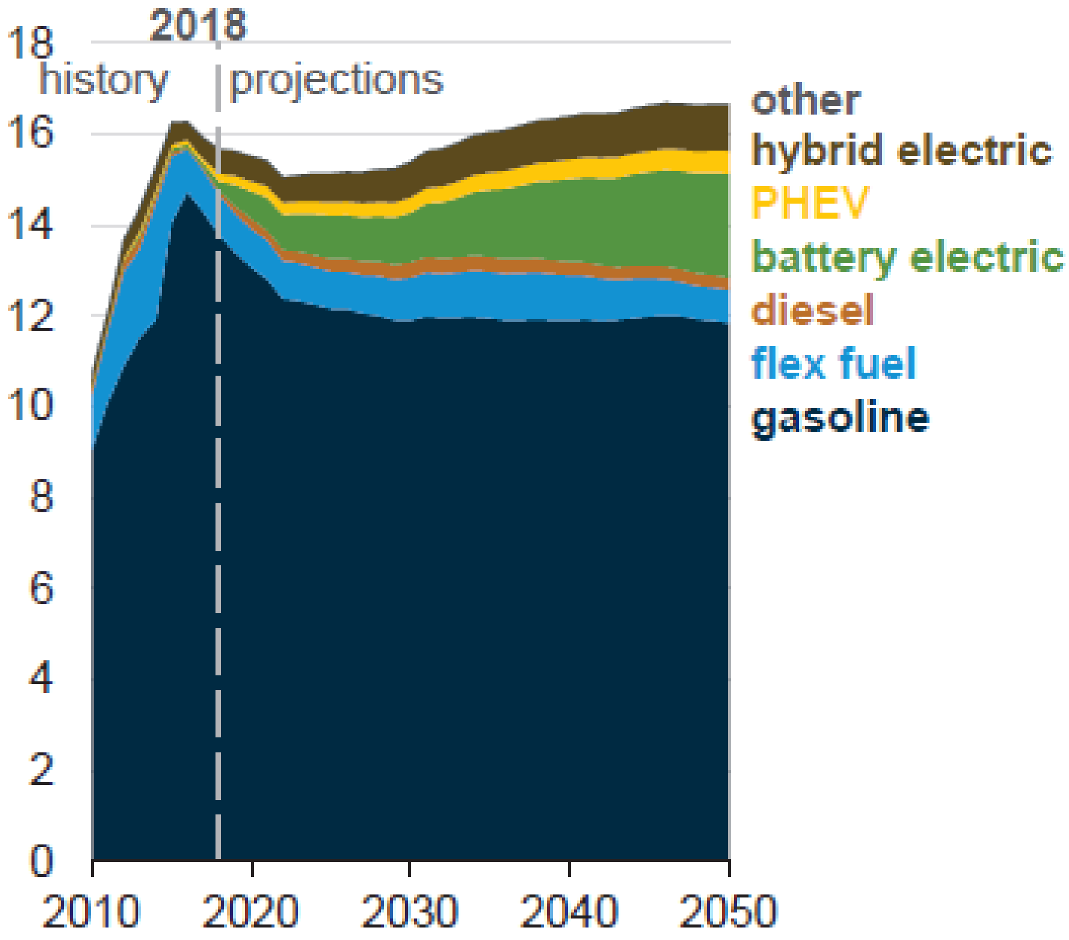


In 2017, transportation accounted for 29% of total U.S. greenhouse gas emissions.

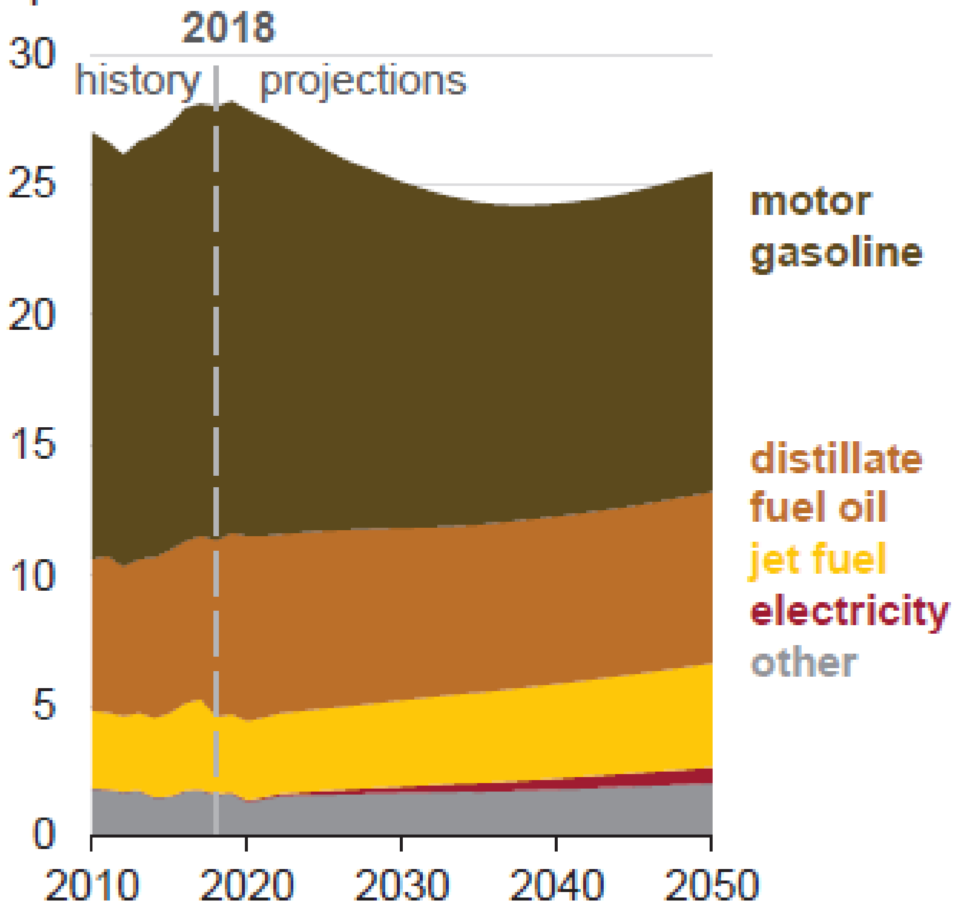
Source: [TEDB, 2019]

Liquid Fuels will Remain Important for Transportation

Light-duty vehicle sales by fuel type (Reference case)
millions of vehicles



Transportation sector consumption (by fuel) (Reference case)
quadrillion British thermal units



Source: EIA 2019 Annual Energy Outlook

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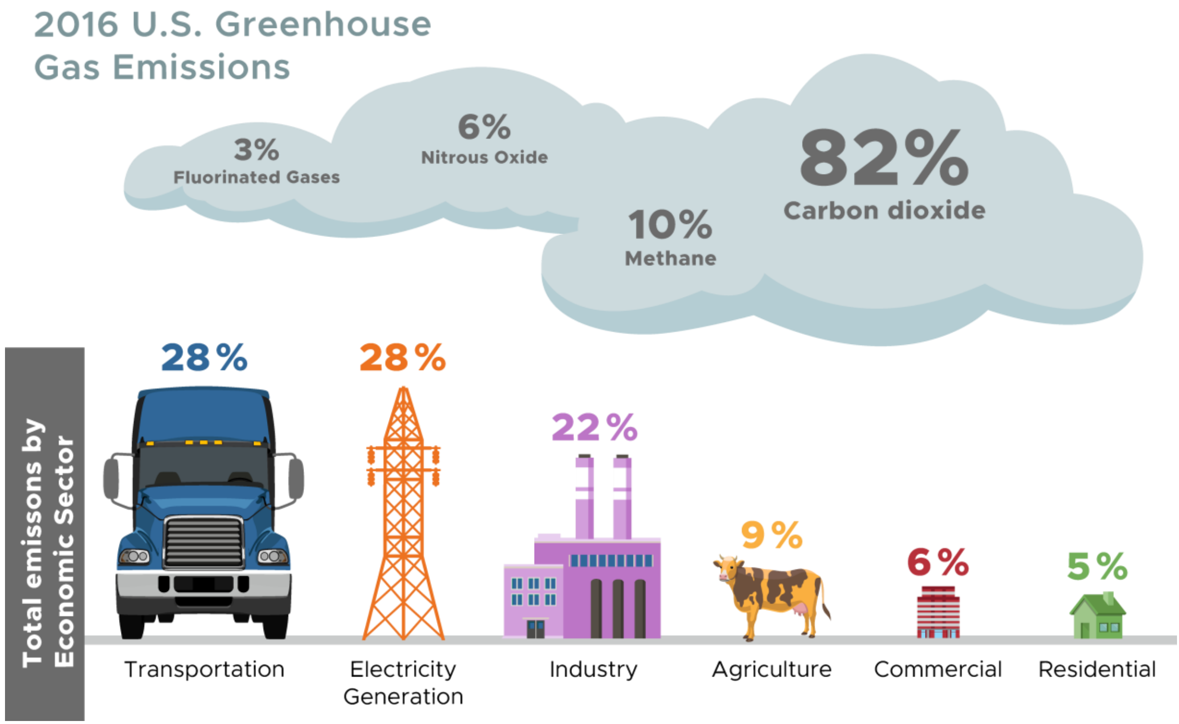
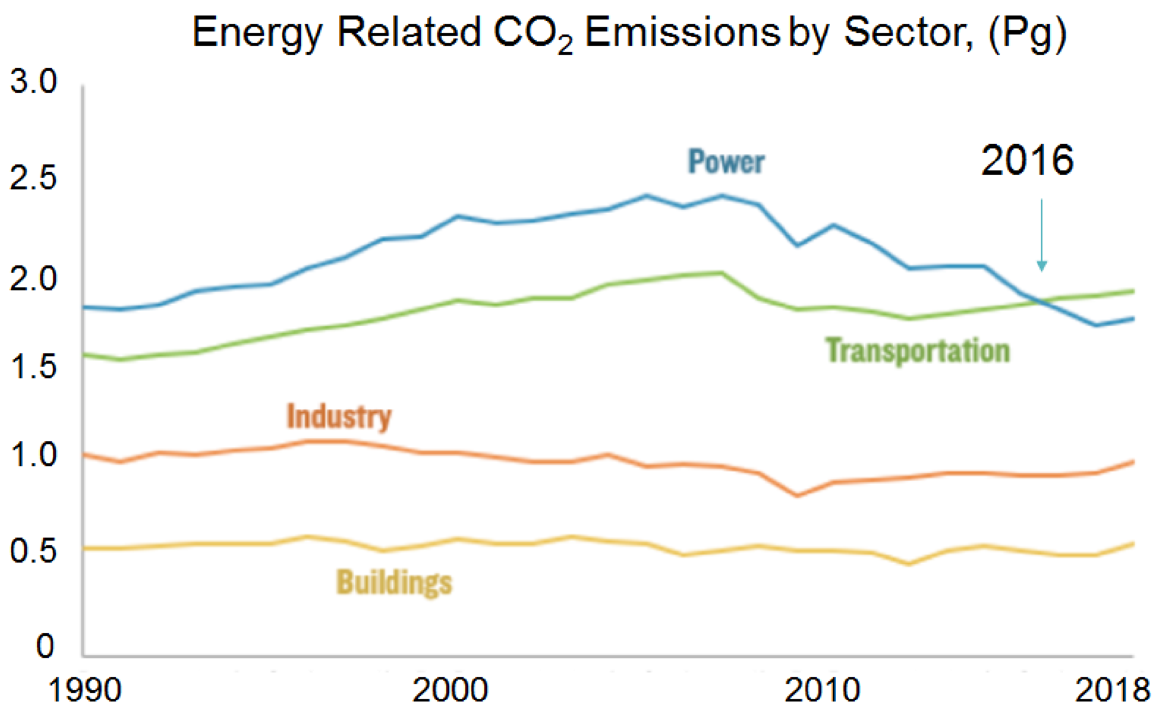
U.S. GHG Emissions

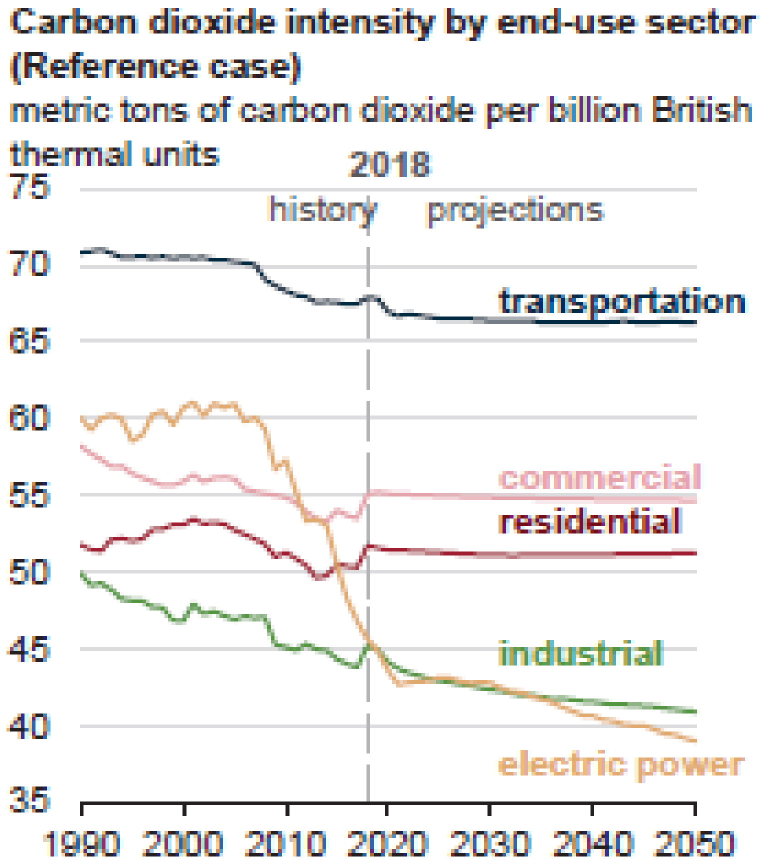


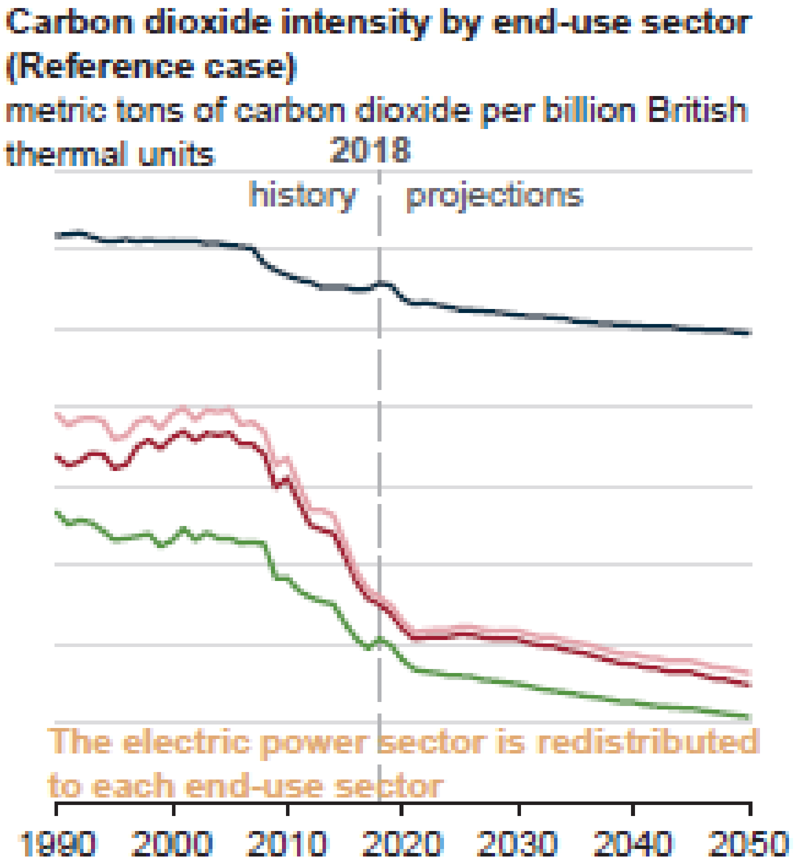


Energy related CO_2 emissions from 1990 to 2018

Source: Rhodium Group

CO_2 Intensity is Projected to Decrease due to Fuel Mix Changes





Note: Carbon dioxide intensities are calculated as carbon dioxide emissions per unit energy output (in British thermal units).

The transportation sector is projected to maintain the highest CO_2 intensity

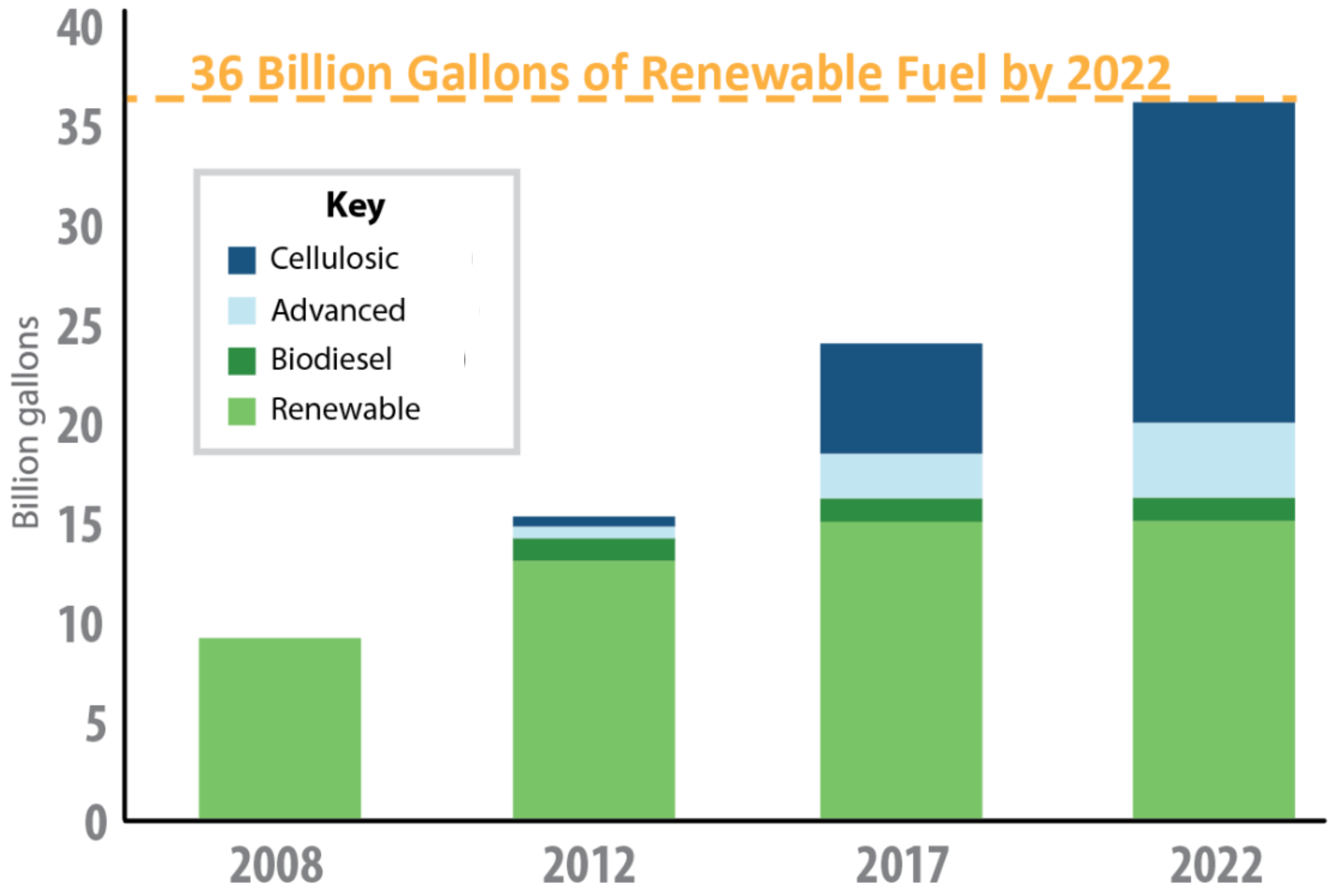
Source: EIA 2019 Annual Energy Outlook

Federal Policies for GHG Emission Reduction in Road-Transportation Sector

Renewable Fuel Standard

- Established in the 2007 Energy Independence and Security Act
- Target 36 billion gallons of renewable fuel production by 2022
- Volume targets adjusted annually by the Environmental Protection Agency
- Fuels must reach a set GHG reduction threshold to qualify as renewable of 20-60% less than petroleum baseline
- Some uncertainty built in beyond 2022

Volume* **Targets** for Renewable Fuel
*Ethanol equivalent basis



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Current Use of Biofuels (2018)

U.S. fuel production by type	Million Gallons	%
Renewable fuel (-20% GHG)	14,955	86%
Ethanol (corn)	14,955	
Advanced (-50% GHG)	2,212	12.5%
Biodiesel	1,855	
Renewable diesel	305	
Other	52	
Cellulosic (-60% GHG)	275	1.5%
Ethanol	6.5	
Renewable natural gas (LNG/CNG)	268	
Other	0.5	

U.S. biofuels provide 5% of total fuel demand

97% of biofuels are produced from starch or vegetable oil

~3% of biofuels are produced from waste C (animal fat or landfill gas)

~0.04% cellulosic ethanol

Source: EPA RIN production data

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State Level Policies and Programs

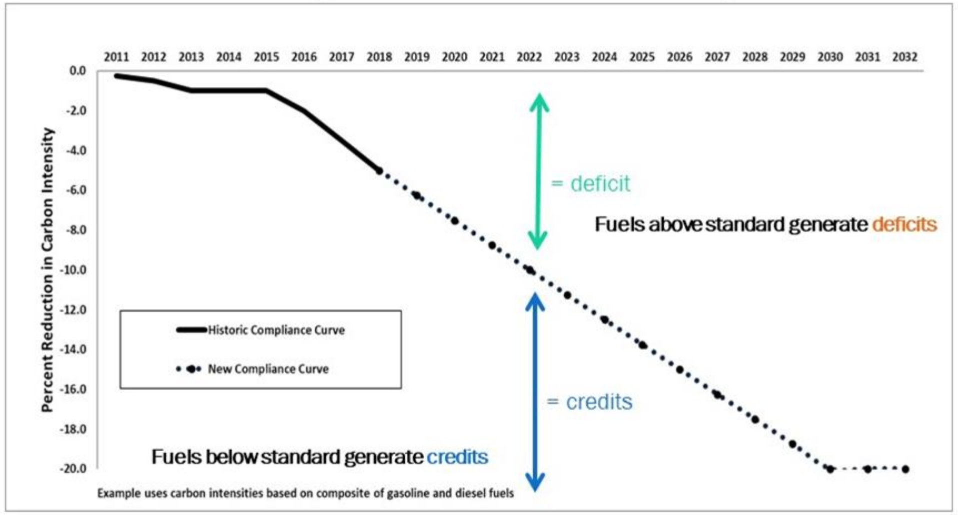
California's Low-Carbon Fuel Standard (LCFS)

- Goal of reducing carbon intensity of transportation fuel pool 20% between 2011 and 2030
- Market for carbon credit transcations exceeding $2 billion in 2018

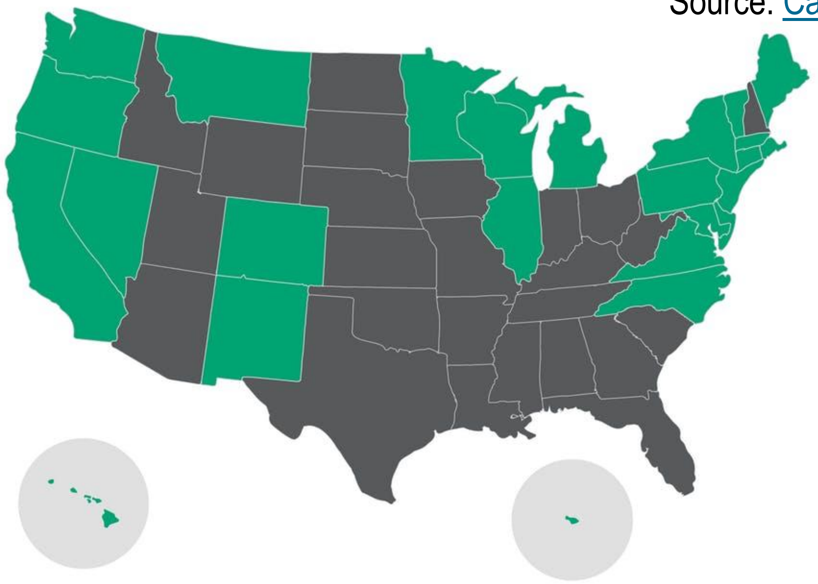
U.S. Climate Alliance

- 24 States and Puerto Rico joined to advance goals of the Paris Agreement
- Reduce GHG Emissions 26-28% below 2005 levels by 2025

Declining Carbon Intensity Curve



Source: California ARB

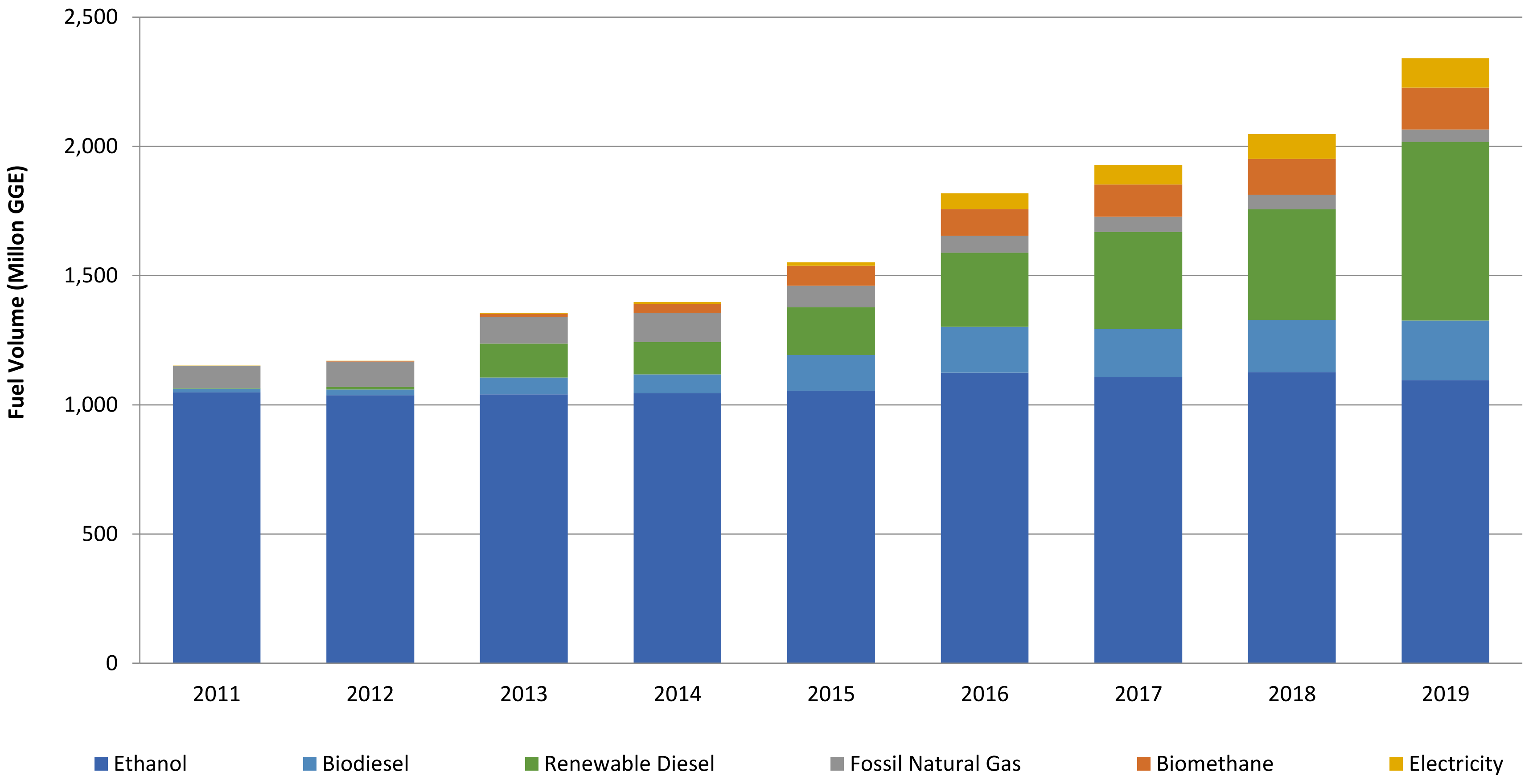


Source: UN Foundation

California Low-Carbon Fuel Standard (LCFS) Provides Incentives for Low-carbon, Liquid fuels

- Adopted in 2009 by the State of California
- To reduce California's transportation fuel carbon intensity (CI) by 10% in 2020 relative to 2010, and another 10% reduction in 2030
  - Gasoline
  - Diesel
  - Alternative fuels
  - Electricity and hydrogen
- GHG emissions for various fuels are determined on well-to-wheels (WTW) basis
  - Carbon intensity (CI), grams of GHGs (CO2, CH4, and N2O)/MJ of fuel, is the measure of GHG emissions associated with producing and consuming a fuel
  - GREET was adapted to CA-GREET to decide a fuel's WTW GHG intensity (CIs)

Renewable Fuels Under LCFS

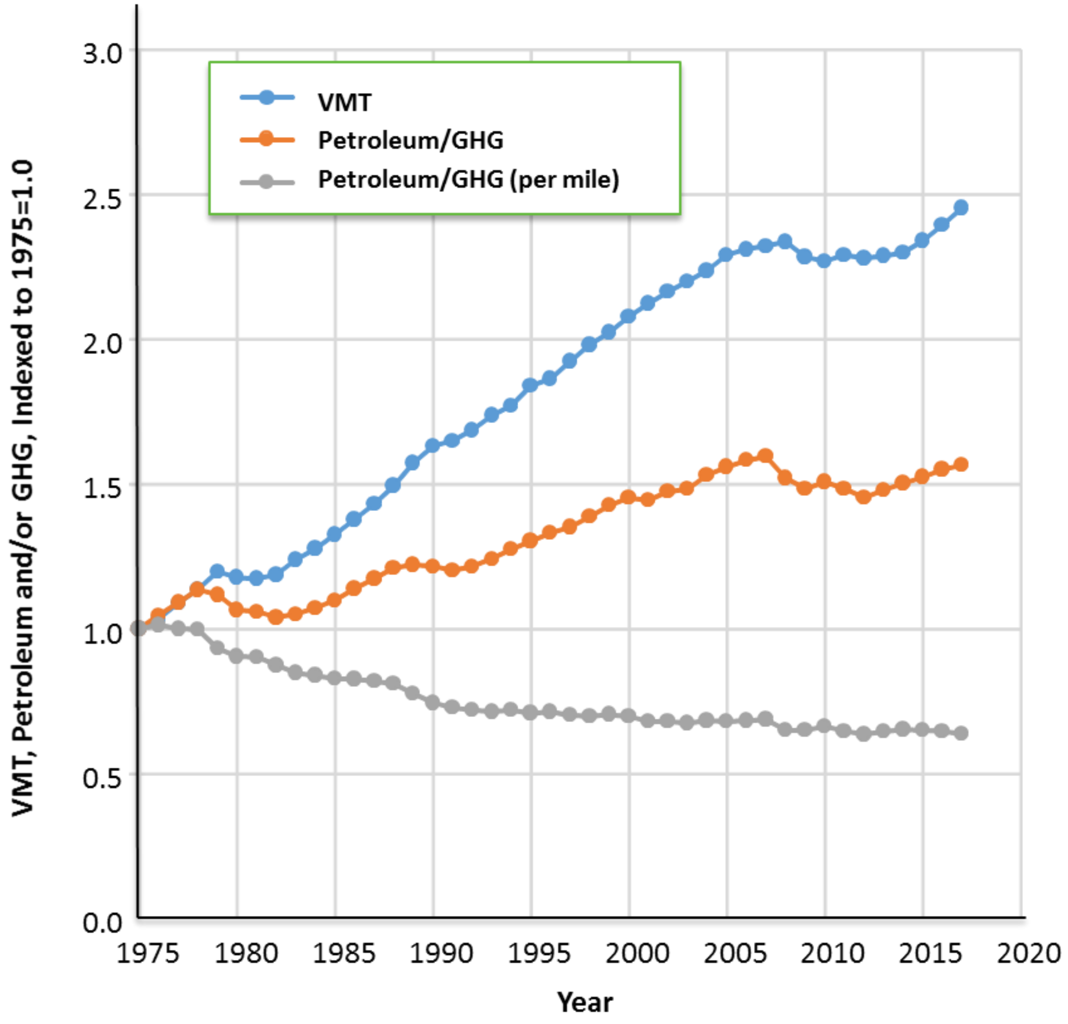


- Utility companies and charging stations which support EV charging can generate LCFS credits.

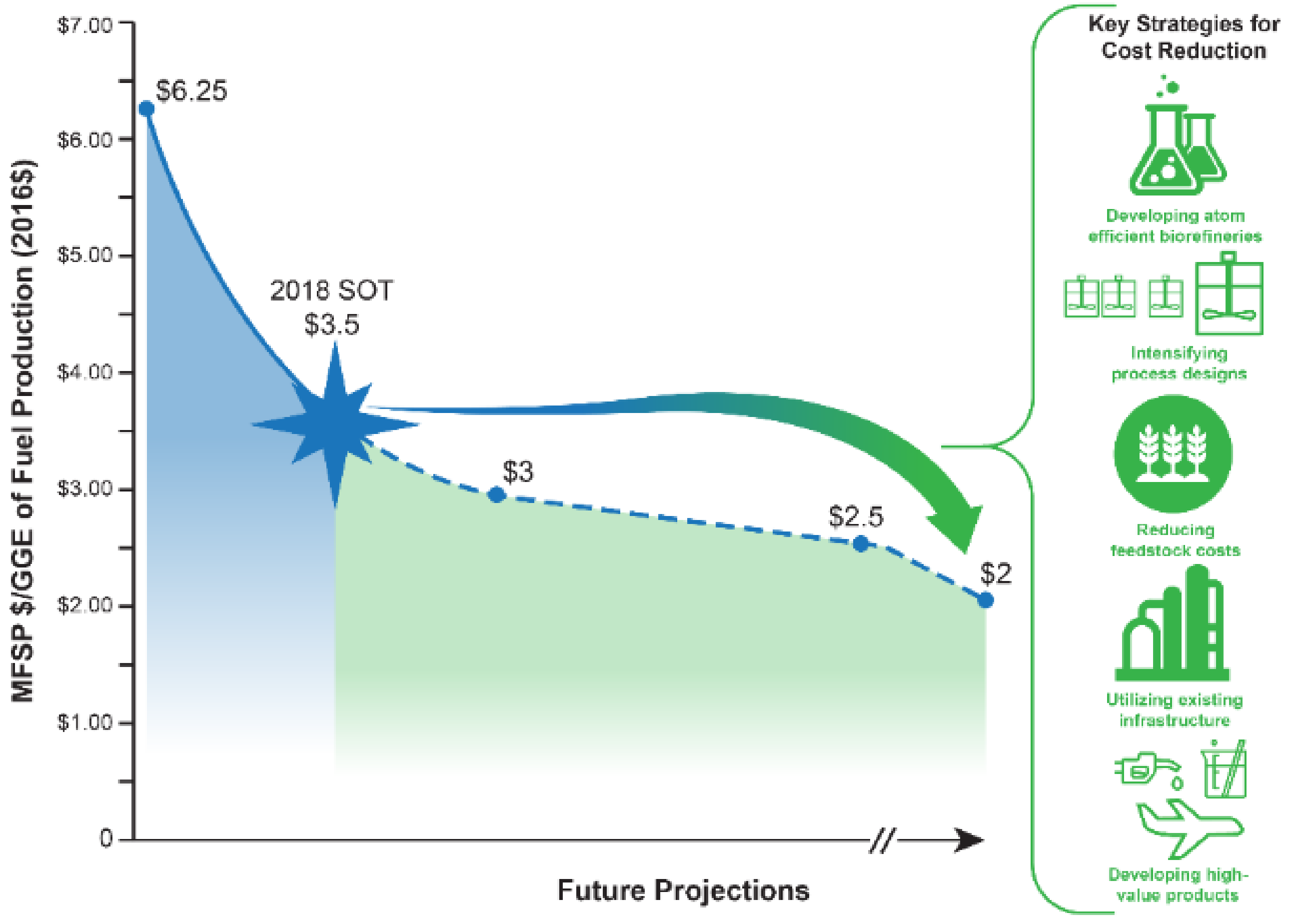
(CARB 2020)

Efforts Within U.S. Department of Energy (DOE)

Improve vehicle ***energy efficiency and emissions***



Reduce the ***cost of biofuels***



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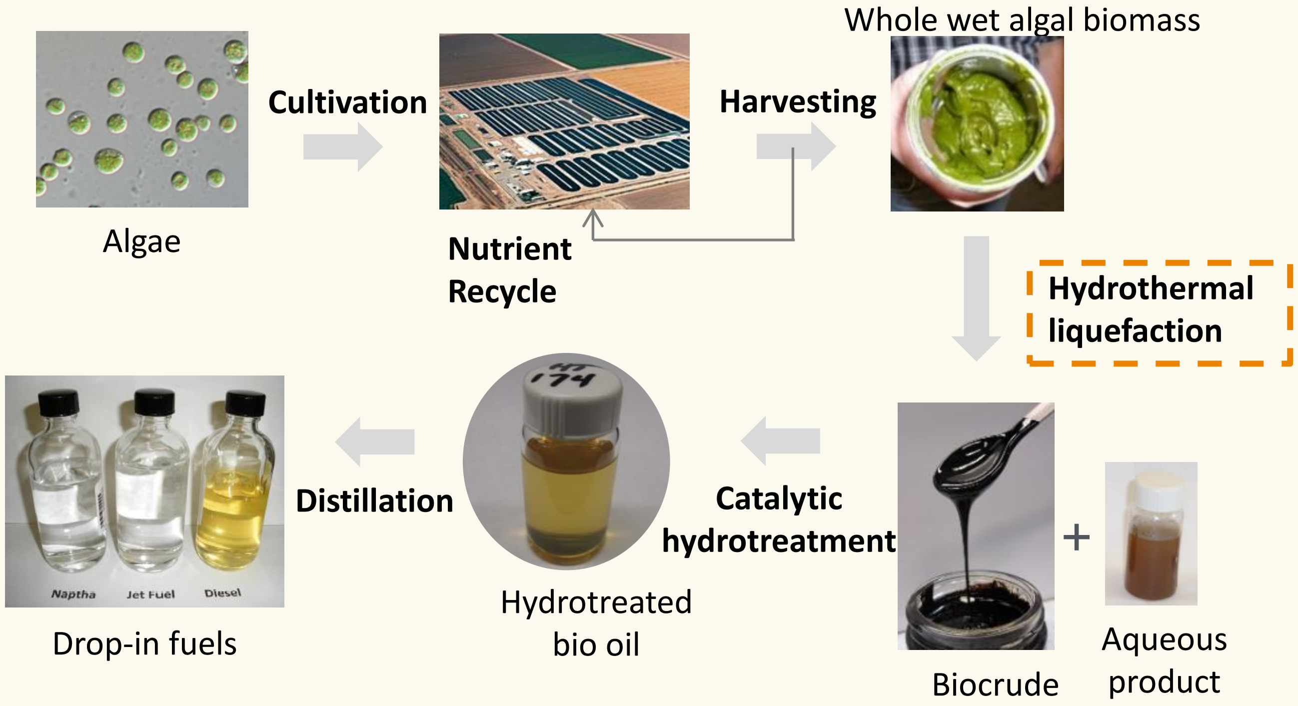
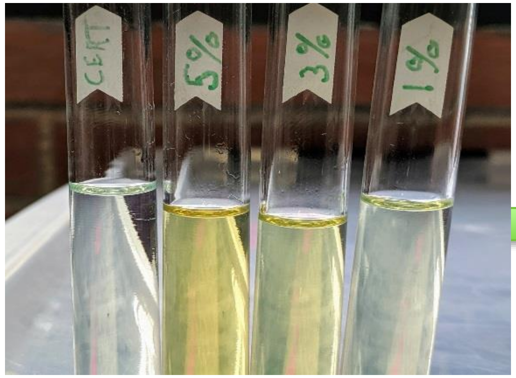
Renewable diesel from hydrothermal liquefaction (HTL) of algae



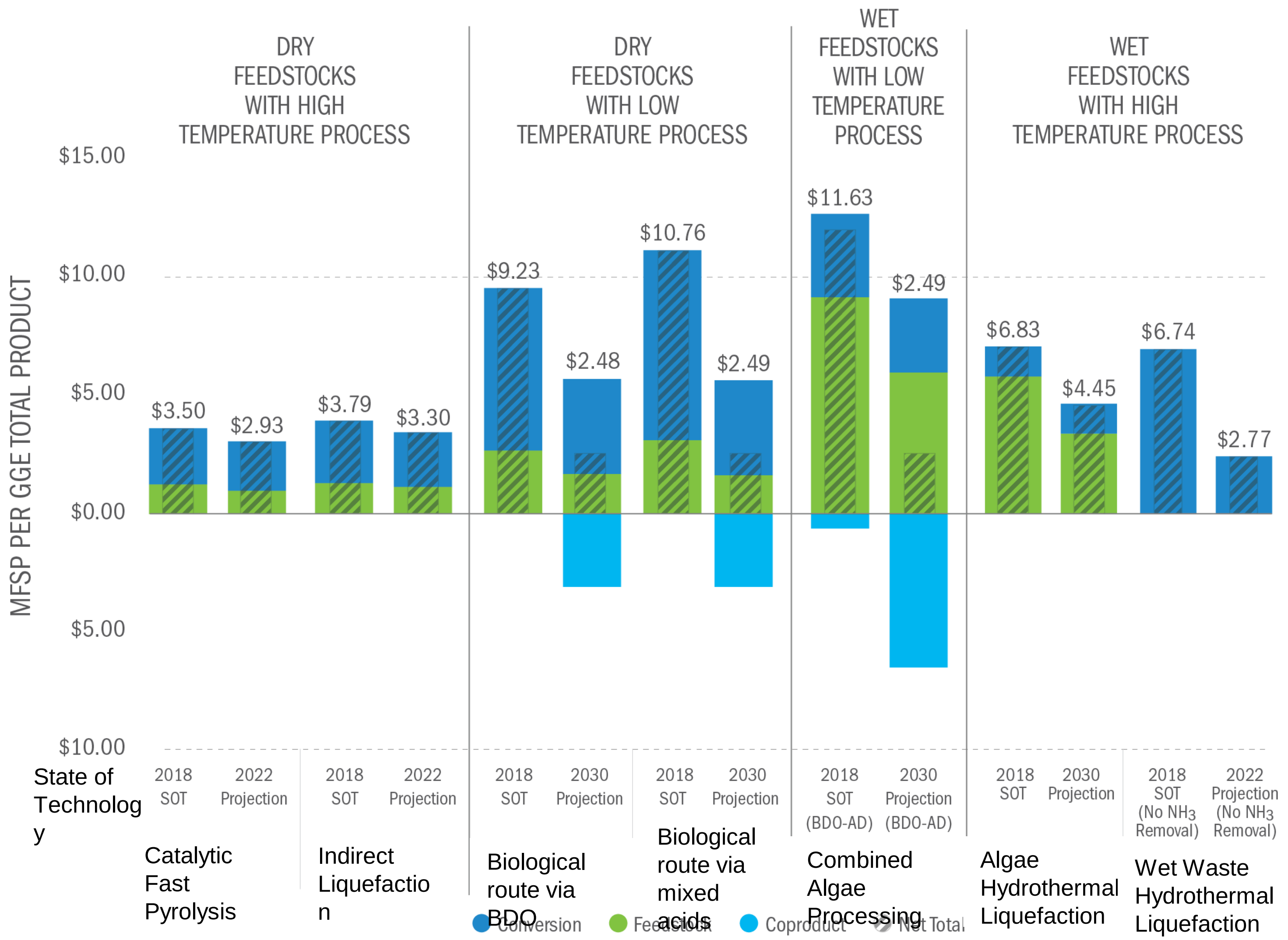
Biocrude Feedstock	Galderia	Chlorella	Tetraselmis
Cetane number	54.4	61.0	58.7
Cloud point (°C)	-14.6	-0.3	3.2
Boiling range (°C)	190-340	160-350	260-350
Simulated distillation T10/T50/T90	205/290/334	182/291/330	286/298/323
Aliphatic carbon Aromatic + olefins H/C	85 15 2	- - -	- - 2

Preliminary data suggest that diesel fuel blendstocks from HTL of algae show promising fuel properties.



	Certification Diesel	1% HTL Blend	3% HTL Blend	5% HTL Blend
Density (g/cm^3)	0.8513	0.850445	0.849383	0.8486
Viscosity (mm^2/s)	4.804027	3.8149	3.799367	3.78475
Vapor Pressure (kpa)	0.2867	0.4967	0.7000	0.8233
Flash Point (°C)	72.7	67.3	63.3	67.3
Cloud Point (°C)	-29.2	< - 50	< -50	< -50
Derived Cetane Number	45.6	45.6	45.4	44.7

Producing Low Cost, Low GHG Biomass Derived Fuels



Life-Cycle GHG emission reduction are ≥ 69% in out-year projections for all technology pathways

Workshop on Hydrothermal Liquefaction: Path to Sustainable Aviation Fuel

- November 17, 2020—November 19, 2020
- This virtual workshop is organized by Pacific Northwest National Laboratory and sponsored by U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office (BETO).
  The objective of this workshop is to identify the role of hydrothermal liquefaction process in producing sustainable aviation fuel and identify the research problems in this area that need to be addressed in the near-term and long-term. Topics included:
  - Current State of Hydrothermal Liquefaction Process
  - How to get the cost down or value up
  - How to get the best fuel quality
  - Next Step in Hydrothermal Liquefaction Process Scale-Up and Commercialization
  - ASTM Approval Process
- https://www.energy.gov/eere/bioenergy/events/hydrothermal-liquefaction-path-sustainable-aviation-fuel-workshop

Summary

- Advanced and cellulosic biofuels production have lagged behind original RFS targets
- Many technology options available and under development but challenges to commercialization in include high capital costs and high feedstock costs.
- Currently no national targets for CO_2 emissions reduction in the USA but California's LCFS is being looked to as a model for the nation
- Drivers for transportation decarbonization include:
  - Vehicle efficiency targets (CAFE)
  - Renewable fuel targets (RFS)
  - State level initiatives (LCFS)
- R&D efforts for renewable fuels at the US Department of Energy focused on:
  - Improving efficiency and emissions (vehicle and system)
  - Reducing cost of biofuels
  - Using lower C intensity fuels and feedstocks
  - Looking at CO_2 as a feedstock resource

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